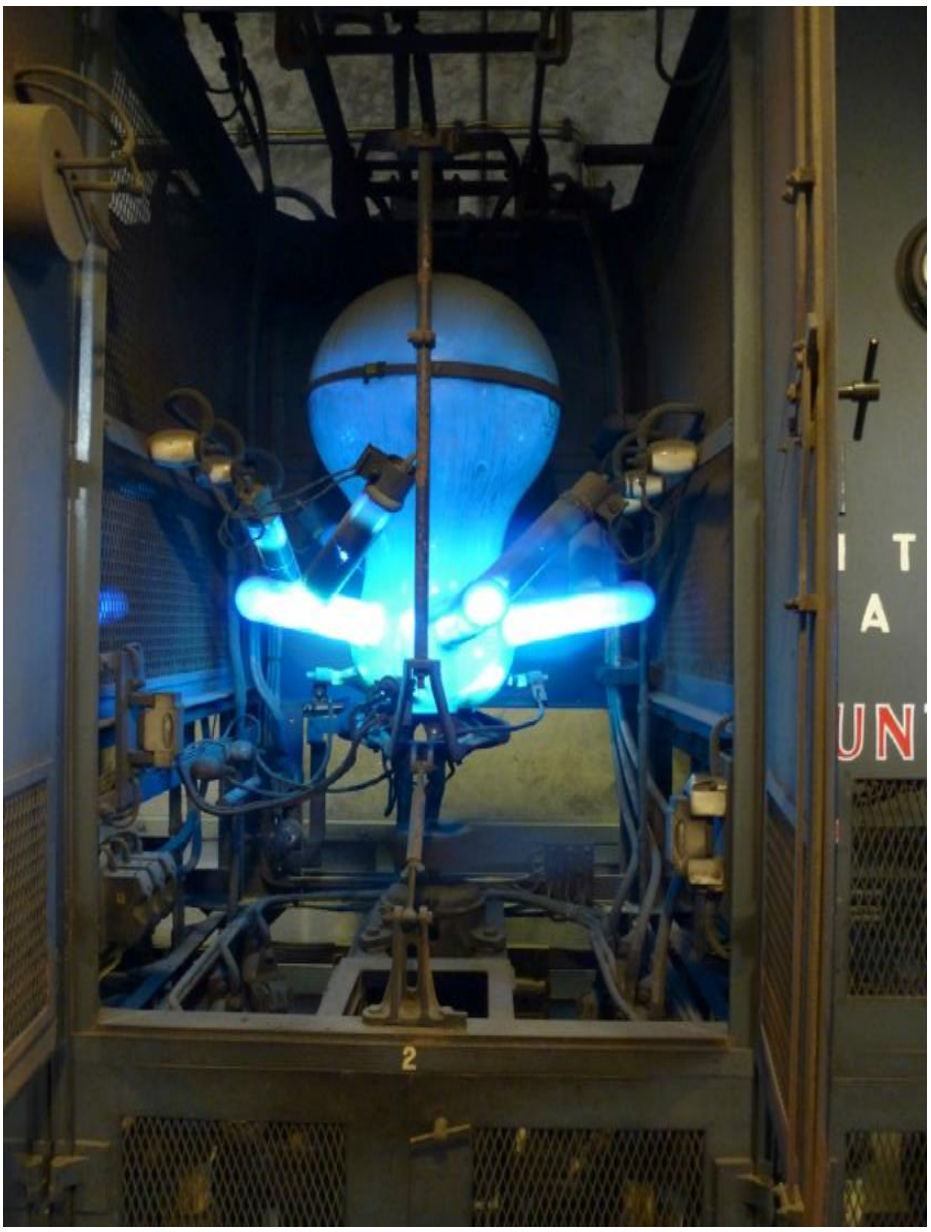
Engineers Australia

Engineering Heritage Victoria

Nomination

Engineering Heritage Australia Heritage Recognition Program

BRUNSWICK WEST MERCURY-ARC TRAMWAY SUBSTATION



March 2019

Front Cover Photograph Caption

Glass bulb mercury arc rectifier in operation at Brunswick West Tramway Substation 'W'. The eerie blue glow from the device is characteristic of this form of rectifier.

The substation was in service from 1936 to March 2019 (refer to page 7).

TABLE OF CONTENTS

1 Introduction [1]

The Brunswick West tram substation was commissioned in 1936 to accommodate increasing tram traffic on the northern part of tram route 55.

It has operated continuously over the 82 years since then.

It has recently been replaced by a new 'package' silicon diode rectifier substation on another site. As such the substation has been shutdown and D C cable connections from it to the tramway overhead and rails removed.

This substation is located in the 'Y' junction where the tram line running west along Dawson Street turns northwards into Melville Road, in Brunswick West - Melway Map 29, C-8. The substation is believed to date from 1935-36 and, remarkably, still has its 600 kW Hewittic [2] glass-bulb mercury-arc rectifier equipment in active service.

The Brunswick West substation contains the following main items of early electrical plant:

- Incoming 6600 volt (AC) switchgear housed in tall brick cells
- An oil/air cooled step-down main transformers for the rectifier bank
- A 600 kW Hewittic mercury-arc rectifier comprising four glass bulb units
- DC negative side high-speed circuit breaker
- An open five-panel switchboard with 600 Volt DC +ve side circuit breakers
- Some other control gear including current limiting resistors

The table of (tramway) substations in use in December 1984 in Biosis / Gary Vines *Tramway Heritage Study*, 2011, dates the mercury-arc rectifier plant as 1936.

The substation is accommodated in an imposing red brick building occupying a prominent position in the 'Y' junction of Dawson Street and Melville Road. A large opening in the front wall of the building is fitted with chain-wire gates with the oil-cooled rectifier transformer clearly visible behind the gates. (This would assist air circulation over the transformer oil cooling tubes).

[1] Verbatim extract from: Miles Pierce, Brunswick West Tramway Substation "W", Report on visit by Miles Pierce. Engineering Heritage Victoria, 16 July 2014.
[2] Refer Appendix 1.

2 Heritage Award Nomination Letter

Learned Society Advisor
Engineering Heritage Australia
Engineers Australia
Engineering House
11 National Circuit
BARTON ACT 2600

Name of work: **Brunswick West mercury-arc Tramway Substation.**

The above-mentioned work is nominated to be awarded an Engineering Heritage Marker.

The substation is located at: **196A Dawson Street Brunswick West 3055, Victoria**

Owner: **Victorian Rail Track Corporation (Vic Track)**

Access to site: The exterior of the site can be viewed from the adjacent public roads. Access into the building is only available with specific approval and escort by officers of Vic Track.

The Nominating Body for this nomination is Engineering Heritage Victoria

David LeLievre
Chair
Engineering Heritage Victoria

Date: March 2019

Substation frontage to Dawson Street, Brunswick West. Image: Miles Pierce.

600 kW Hewittic mercury-arc rectifier cubicles. Image: Miles Pierce.

3 Heritage Assessment

3·1 Basic Data

Other/Former Names: None known
Location: 196A Dawson Street Brunswick West 3055, Victoria
Local Govt. Area: Moreland
Owner: Vic Track
Current Use: Retired and disconnected in March 2019
Former Use: Tramway 600V Traction Substation
Designer: Former Melbourne & Metropolitan Tramways Board
Maker/Builder: Rectifier plant made by Hewittic Electric Co. (UK)
Year Started: 1935
Year Completed: 1936
Physical Description: Mercury-arc rectifier station 6.6 kV AC to 600 Volts DC
Physical Condition: Brick building with electrical plant inside

3·2 Heritage Listings

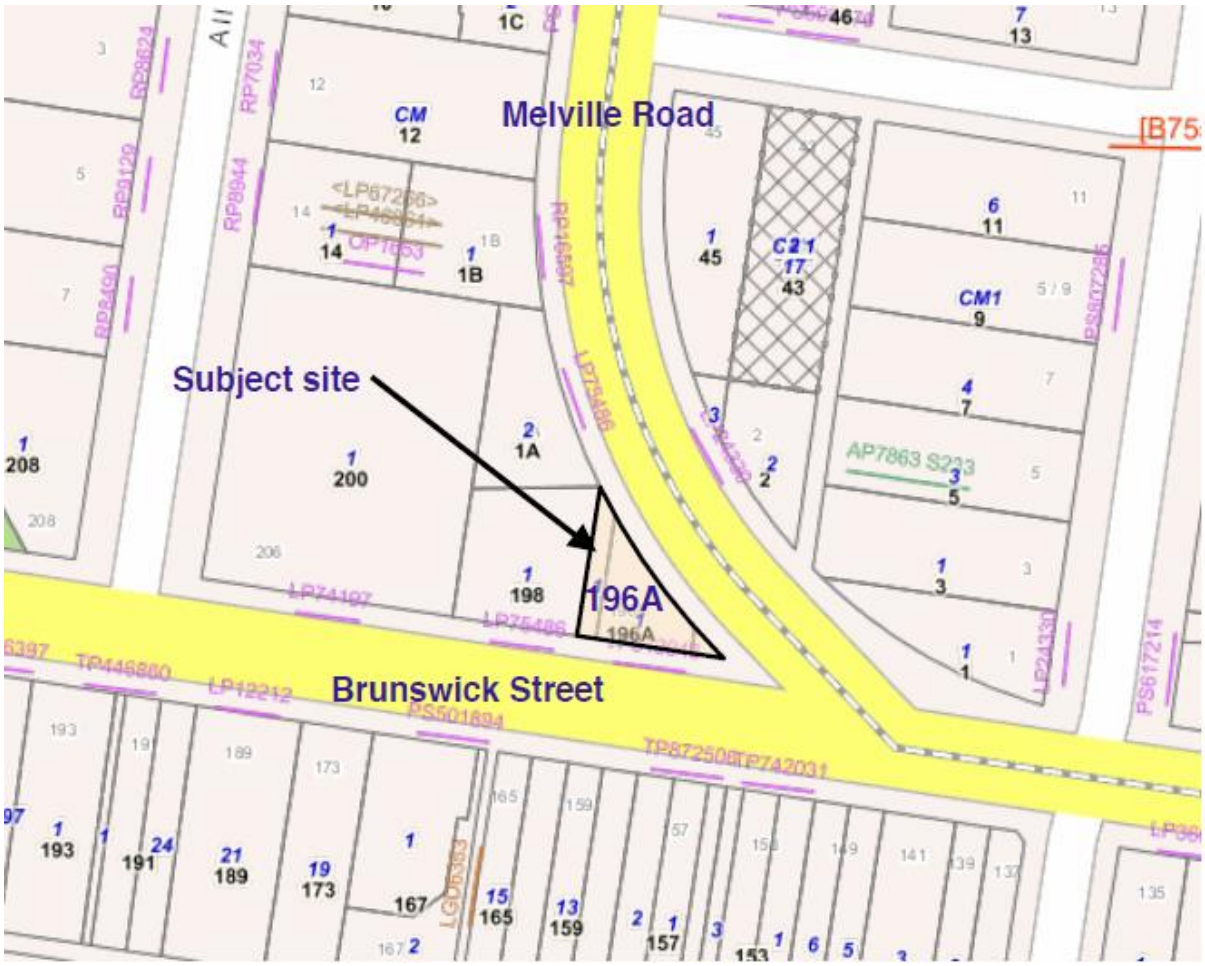
Local Heritage Overlay Information [3]
This place has a Local Heritage Overlay (HO) within the City of Moreland planning scheme. The HO number is HO64

No others known.

An Application to nominate a place or object for inclusion in the Victorian Heritage Register was made on 28 June 2018 by Miles Pierce on behalf of Engineering Heritage Victoria. Progress on this application is not known.

[3] Verbatim extract from: Miles Pierce, Brunswick West Tramway Substation "W", Report on visit by Miles Pierce. Engineering Heritage Victoria, 16 July 2014.

4 Location Map [4]:



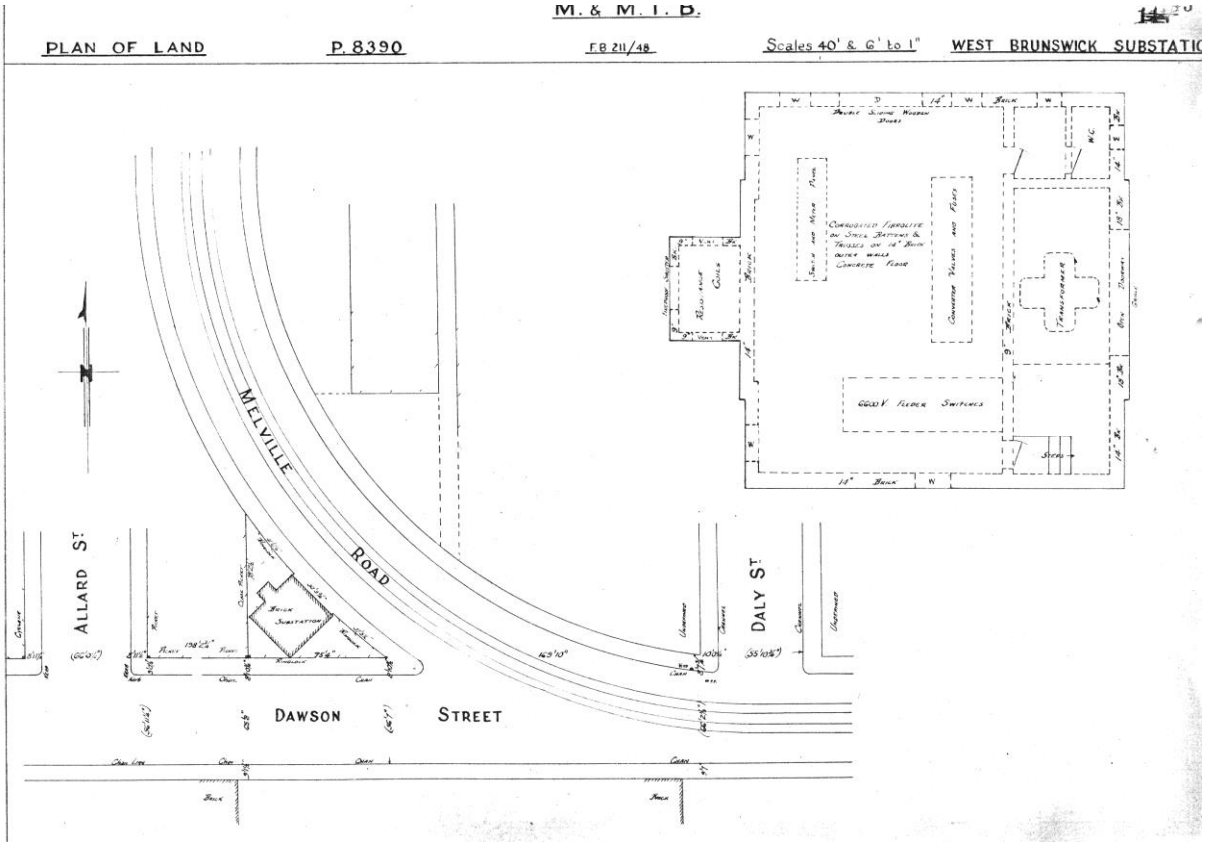
Site plan. The substation is located on the shaded lot 196A labelled as 'Subject site'
Image: https://maps.land.vic.gov.au/Lassi/

Local Government Area: MORELAND
Code: 351
Locality: Brunswick West
Parish: Jika Jika
Code: 2796
Lot: 1
Plan: TP5190046
Property Number: 5757
Address: 196A Dawson Street Brunswick West 3055

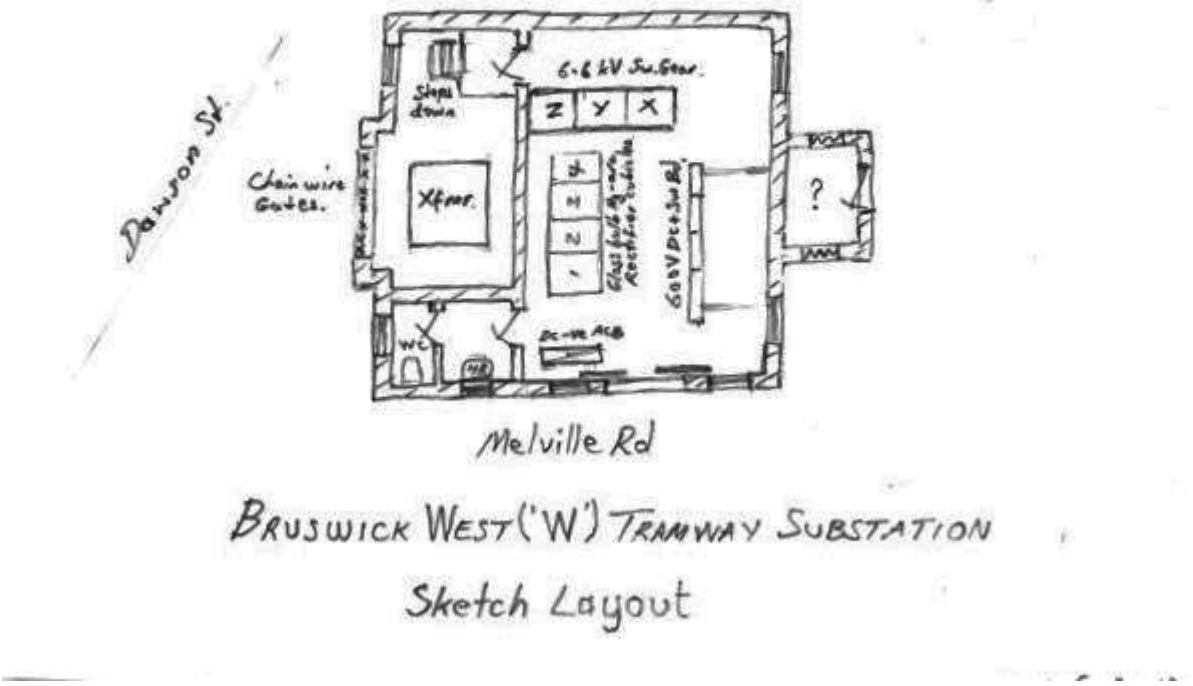
[4] Verbatim extract from: Miles Pierce, Brunswick West Tramway Substation "W", Report on visit by Miles Pierce. Engineering Heritage Victoria, 16 July 2014.

5 Sketches of Building Layout and Single Line Electrical Diagram

5·1 Location Plan and Floor Plan



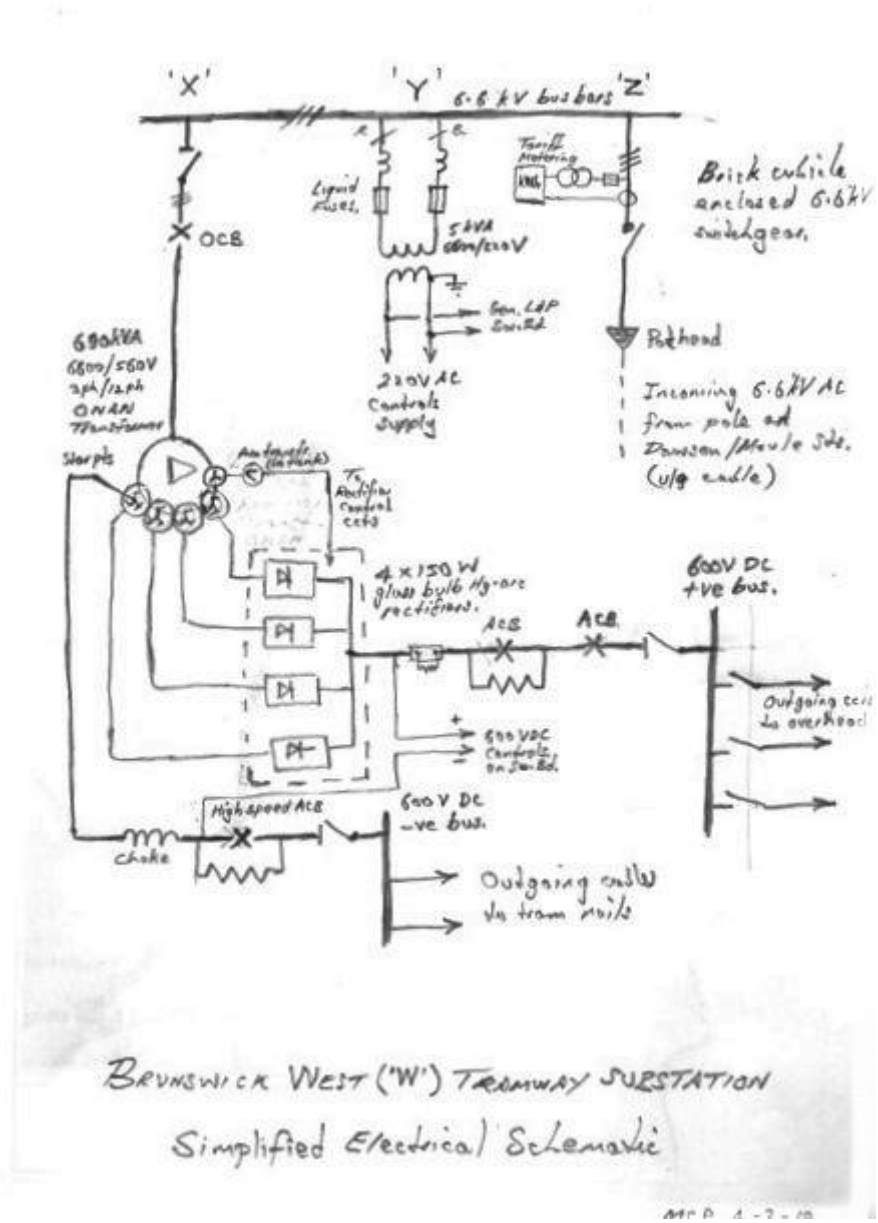
5·2 Sketch Plan of Building



Sketch Plan of Building. From left, top to bottom: 1) Transformer (6.6 kV to multiple voltage to drive Mercury Arc Rectifiers; 2) Toilet and hand basin; 3) 6.6 kV switchgear in three brick cells marked X (circuit breaker to feed main transformer), Y (Auxiliary Transformer 6.6 kV to 240 volts single phase), and Z (incoming 6.6 kV supply from overhead circuit in Dawson Street); 4) Mercury Arc Rectifiers (4 bulbs) in steel cabinets; 5) 600 Volt DC Negative High Speed Circuit Breaker; 6) 600 Volt DC switchboard.

Sketch by Miles Pierce 5 March 2019

5·3 Sketch of Electrical Single Line Diagram



Electrical Single Line Diagram. The top of this diagram shows the 6.6 kV Alternating Current incoming supply. This equipment is contained in brick cells and a three phase bus runs along the top of the cells. The Auxiliary Transformer is single phase of 5 kVA capacity.

Below this is shown the transformer with multiple windings on the low voltage side to feed the Mercury Arc Rectifiers. The 600 Volt Direct Current output is protected by a pair of Air Circuit Breakers on the positive side and feeds three outgoing feeders to the overhead tram traction wires via isolators.

At the bottom of the diagram is a single negative 600 Volts DC High-speed Air Circuit Breaker which feeds to the tram rails via two circuits.

Sketch by Miles Pierce 4 March 2019

6 Assessment of Significance

6·1 Historical Significance [5]:

From an engineering heritage perspective, this substation is particularly significant on account of its extant, and currently still in-service Hewittic glass-bulb mercury-arc rectifier equipment and associated AC and DC electrical plant. In-situ glass-bulb mercury-arc rectifier equipment is becoming rare and such plant still in active service for its original purpose is rare indeed, particularly for equipment of this power rating (600 kW).

CitiPower has a multiple glass-bulb mercury-arc rectifier at its Russell Place zone substation in the city (former MCCESD [6] substation) which is still energized and can be demonstrated supplying a 'dummy load', however it was withdrawn from active service in late 2003 when the last DC customer was disconnected from the public 460/230 V DC supply. EHV knows no other still in-service plant of this type anywhere else in the State. The Brunswick West rectifier plant is likely to be unique in Victoria and quite possibly nationally. For its rarity, it is of state and national significance.

Obtaining a unidirectional electric current flow by means of an arc struck between a mercury pool and carbon electrodes – diode action - was first discovered in 1882. The commercial development of this discovery for the conversion of AC to DC (rectification) was pioneered by Peter Cooper-Hewitt from 1900. By the mid-1920s reliable industrial mercury-arc rectifiers were available from several makers with the earlier problems of propensity for 'back-firing' largely overcome [7]. From this time they started to supplant rotary converters, particularly for low to medium power demands, where they offered higher conversion efficiency. As essentially 'static plant', maintenance was also minimal.

An alternative steel-tank version was developed for higher power applications although these units normally entailed the additional complication of continuous evacuation using specialised vacuum pumping plant.

By 1935 the capacity limit for glass-bulb mercury arc rectifiers was 500A, 600 V DC (300 kW), however higher capacities could be achieved by operating two or more bulbs in parallel. The 600 kW rated Hewittic mercury-arc rectifier installation at Brunswick West substation has four, six-pole glass-bulbs, each housed in a sheet-steel cubicle with a propeller type cooling fan whose operating speed varies with the rectifier load current [8].

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[5] Verbatim extract from: Miles Pierce, Brunswick West Tramway Substation "W", Report on visit by Miles Pierce. Engineering Heritage Victoria, 16 July 2014.

[6] MCCESD = Melbourne City Council Electricity Supply Department

[7] Refer to Appendix 2 for a more detailed explanation of operation.

[8] Duffy M C, 2003, *Electric Railways 1880-1990*, The IEE.

Rectifier transformer with substation front door at the right. 6.6 kV to 12 phase Mercury Arc Rectifier interface for 600 Volts DC. This is a complex transformer specially built for its purpose.
Image: Miles Pierce.

6·2 Historic Individuals or Association:

No individuals involved in this site have been identified.

6·3 Creative or Technical Achievement:

The conversion of Alternating Current (AC) electricity to Direct Current (DC) has evolved through several technologies during the century and a half since the beginning of the mass use of electric power.

The first generation of plant was the dynamo (DC electric rotating generator) which could be driven by an AC electric motor (a motor-generator) or directly from a prime mover such as a steam engine, steam turbine or diesel engine.

The second generation was the rotary converter, a single rotating electric machine which took in AC current and delivered DC current. This machine cleverly combined the functions of a motor-generator set, and by using a single rotating armature whose windings were connected to AC slip rings at one end and a conventional DC commutator at the other. By needing only a single pair of main bearings it afforded improved conversion efficiency and offered substantial space savings. The rotary converter was invented in 1888 [9] and was dominant from the 1890s until the 1930s, with many machines installed and continuing in service throughout the first half of the twentieth century and beyond.

The third generation was the mercury-arc rectifier, as found at Brunswick West. The mercury-arc rectifier was invented by Peter Cooper Hewitt around 1902 and began a refinement process that extended into the 1950s [10].

The fourth generation of plant for high power AC to DC conversion was the solid state electronic rectifier, typically silicon diodes or thyristors that are widely used today. These devices have no moving parts, are much smaller (power-for-power) and are exceedingly reliable. Whilst there have been some advances in the types of electronic components used this type of rectifier has remained much the same in

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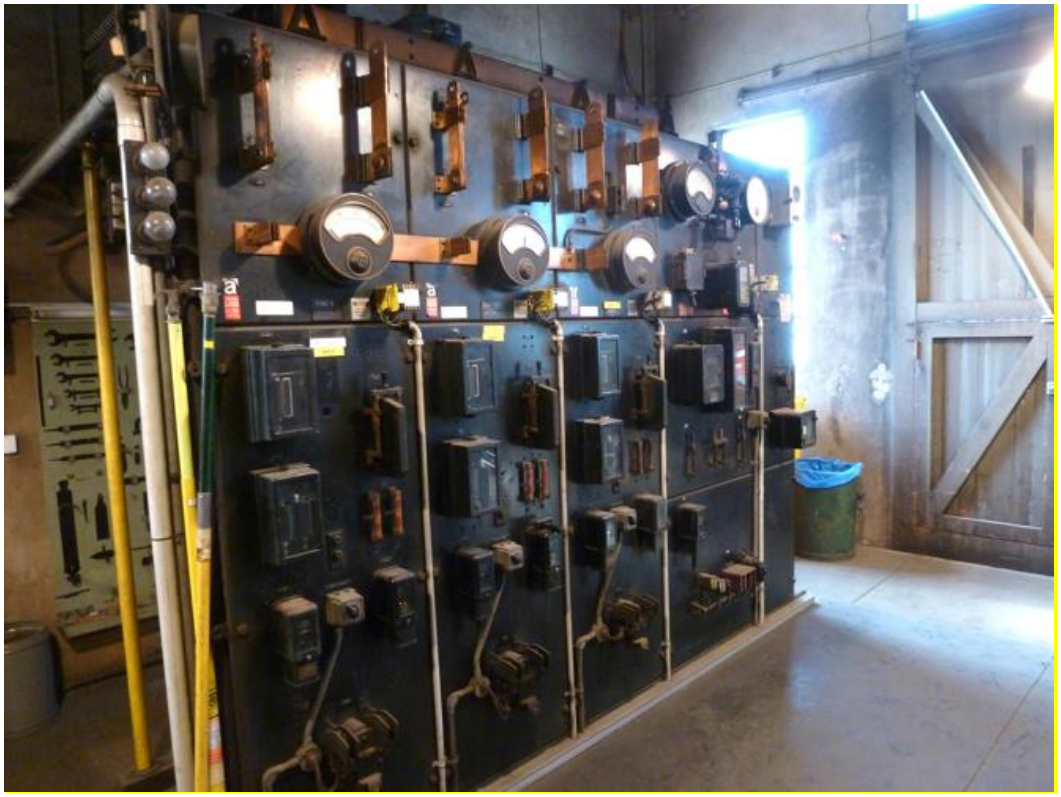
[9] An inventor named Charles S. Bradley is generally credited with the invention of the rotary converter as early as 1888. However, during the early 1890s, Benjamin G. Lamme, of the Westinghouse Electric & Manufacturing Company in Pittsburgh, Pennsylvania, also laid claim to its invention. It is certainly likely that the Westinghouse Company was responsible for improvements to the basic design of these machines during this period. [The Rotary Era, Part 1, Early AC-to-DC Power Conversion, by Thomas J. Blalock, IEEE Xplore Digital Library].

[10] About 1930, control grids were added to the mercury-arc valve with pool cathodes. These grids were used to control the conduction progression required for regulating the starting process. [The Rotary Era, Part 1, Early AC-to-DC Power Conversion, by Thomas J. Blalock, IEEE Xplore Digital Library].

principle from the 1950s until the present time. They can be found in sizes from microscopic scale to thousands of Megawatts for high power electric transmission applications.

The uses of DC, once the electricity supply system had decided to use AC systems almost universally, was primarily for industries requiring DC, for traction applications such as electric trains and trams, aluminium smelting and the conversion of AC to DC and DC to AC for high power transmission systems.

Of course our interest, as far as Brunswick West Substation is concerned, is to supply DC to the Melbourne Electric Tramway system. This may seem like a somewhat humble task but we should not lose sight of the fact that Melbourne's tram system is one of the largest in the world, moves vast numbers of Melbourne commuters around every day and is much loved by most Melbournians.



Direct Current Positive Switchboard (600 Volts DC). Image: Miles Pierce.

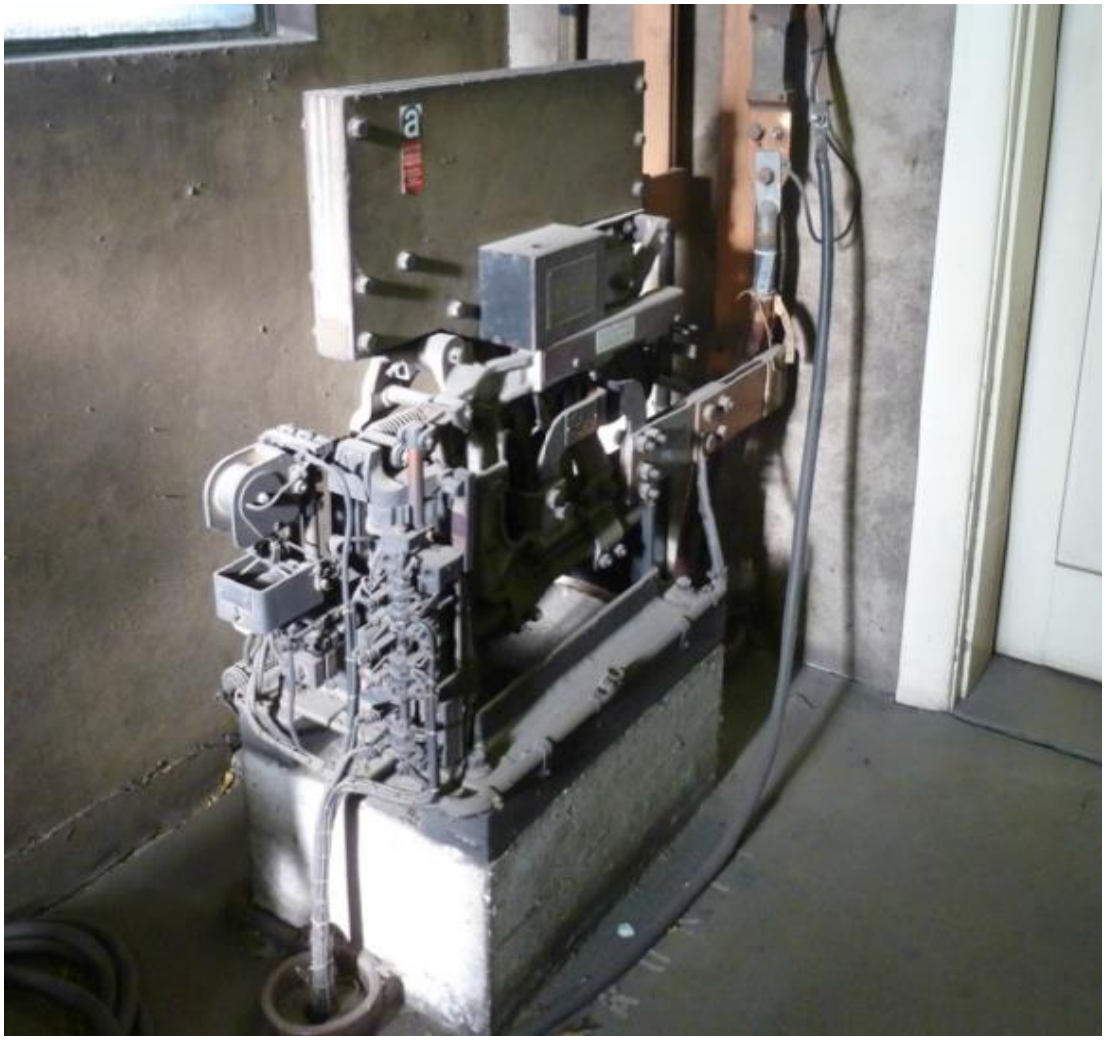
6·4 Research Potential:

Much research remains to be done on the supply of DC to trains and trams in Australia. Melbourne is the most obvious place to centre this research as Melbourne is home to a very large and old suburban electric train network and a very large tramway system.

These two systems operate at significantly different DC voltages: 1500 Volts in the case of the trains and 600 Volts in the case of the trams.

These systems are old enough to have experienced almost all forms of DC generation and AC to DC conversion throughout the lives of the systems. This augers well for their research potential.

Engineering Heritage Victoria has made a modest start on this task with a previous nomination for the Malvern Tramway Substation (rotary converters) before this nomination which looks at a mercury-arc rectifier installation.



DC negative high-speed circuit breaker. Image: Miles Pierce.

6·5 Social:

Tramway substations are essentially ‘invisible’ to the general public as their function is seen as inexplicable and mysterious by most members of the public.

However the tramway system itself is highly visible to the public and much admired by most Melbournians. Millions of Melburnians travel by tram finding the system convenient, cheap to use, reliable and a pleasant form of public transport.

Engineers in the community will connect the substations with the functioning of the trams.

6·6 Rarity:

The substation is quite rare. It is the last remaining mercury-arc substation supplying (or previously supplying) 600 Volt DC power to the Melbourne Tramway system.

The only other mercury-arc rectifier station known in Victoria is the Russell Place electricity substation which previously supplied DC power to electricity customers in the Melbourne CBD. This substation is still in service with **Citipower** supplying AC power to customers however the DC system located in this substation has been retired and is maintained by **Citipower** as a heritage artefact. It can be operated to demonstrate its function working with a dummy load.

No substation of similar age and equipment is known in the tramway or railway systems in other Australian states.

The conservation of similar substations in other countries is not known.

6·7 Representativeness:

The substation is representative of other substations which previously supplied the Melbourne Tramway system during the mercury-arc period from the 1920s until the technology was progressively superseded by solid state electronic rectifiers from the 1950s.

6·8 Integrity/Intactness:

The functional building and the internal electrical plant and equipment appear essentially unaltered from their original ‘as built ‘and ‘as supplied’ form.

Some additional control relays and control switches have been added to the 600 V DC switchboard, either to replace certain small original items or to add new control and supervisory features. Their visual and functional impact is minor.

6·9 Statement of Significance:

See section 5 above.

6·10 Area of Significance:

This site is of state and national significance. It may also be of international significance.

7 Interpretation Plan

7·1 General Approach

This site is not suitable for open interpretation as the owner would not welcome uninvited visitors to the site. Inspection of the substation interior can only be arranged with some difficulty at considerable notice by the cooperation of individuals within Vic Track or Yarra Trams known to Engineering Heritage Victoria.

The site should therefore be subject to **VIRTUAL INTERPRETATION** which means no interpretation on site and no Heritage Recognition Ceremony.

8 Acknowledgments, Authorship and General Notes

8·1 Acknowledgments

This document was based largely on the Application to nominate the place for inclusion in the Victorian Heritage Register written by Miles Pierce on 28 June 2018 on behalf of Engineering Heritage Victoria.

8·2 Nomination Preparation

This nomination was prepared by:

Owen Peake
Engineering Heritage Victoria
4 Islington Street
Collingwood Victoria 3066
Phone: +61 3 9419 0820
Email: owen.peake@bigpond.com

8·3 General Notes

This document has been prepared in accordance with the Commonwealth Government Style Manual for authors, editors and printers, Sixth Edition, revised by Snooks & Co, 2002.

9 Recommendations: [11]

It is recommended that:

8.1. The Brunswick West Tramway Substation 'W' and its extant 600 kW Hewittic glass-bulb mercury-arc rectifier equipment and associated electrical plant be formally recognised under the EHA's Engineering Heritage Recognition program.

8.2. That Yarra Trams and the owner VicTrack be encouraged to retain and preserve the substation and its extant electrical plant.

8.3. Some further details of the electrical plant be obtained and recorded. This includes a high quality copy of the electrical schematic diagram found in the substation rolled up into a scroll. Photographing this document proved very challenging.

[11] Verbatim extract from: Miles Pierce, Brunswick West Tramway Substation "W", Report on visit by Miles Pierce. Engineering Heritage Victoria, 16 July 2014.

Appendix 1: History of Hewittic Electric Co [12]

Hewittic Electric Co of Hersham, Walton-on-Thames, England.

Manufacturers and suppliers in Great Britain.

1906 Company formed as Westinghouse Cooper-Hewitt Co Ltd.

1908 British Westinghouse Electric and Manufacturing Co Ltd announced that Cooper Hewitt mercury discharge lamps would be manufactured in the UK, having previously been made in France and Germany.

1909 Converted into private company.

1911 Westinghouse Cooper-Hewitt Co demonstrated mercury vapour lamps at the Electrical Exhibition.

1920 Name changed to Hewittic Electric Co.

1937 Manufacturers of electrical machinery. "Hewittic" Electrical Appliances.

1938 Manufacturers of glass bulb rectifiers.

1946 Formed Hackbridge and Hewittic Electric Co Ltd by acquiring the transformer manufacturing company of Hackbridge Electric Construction Co and the New Switchgear Construction Co.

1947 Hackbridge and Hewittic Electric Co went public.

1960 Acquired 96% of Bertram Thomas (Engineers) Ltd.

1960 Formed Combined Electrical Manufacturers Ltd as result of merger with Switchgear and Cowans Ltd, in which this company already had a significant shareholding and one with which there was an exchange of 3 directors.

1961 Manufacturers of power and distribution transformers, mercury rectifiers, mercury vapour lamps, electrical switchgear and high power quantity lamps and overhead line switchgear.

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[12] From Grace's Guide.

1961 In conjunction with Easun Engineering Co had formed Hackbridge Hewittic and Easun Co of Madras which was manufacturing transformers in India.

1969 As result of GEC acquiring English Electric Co and AEI, Hackbridge and Hewittic Electric became part of GEC Transformers.

Appendix 2: How does a Mercury-arc Rectifier Work? [13]

Operation of the rectifier relies on an electrical arc discharge between electrodes in a sealed envelope containing mercury vapour at very low pressure. A pool of liquid mercury acts as a self-renewing cathode that does not deteriorate with time. The mercury emits electrons freely, whereas the carbon anodes emit very few electrons even when heated, so the current of electrons can only pass through the tube in one direction, from cathode to anode, which allows the tube to rectify alternating current.

When an arc is formed, electrons are emitted from the surface of the pool, causing ionization of mercury vapour along the path towards the anodes. The mercury ions are attracted towards the cathode, and the resulting ionic bombardment of the pool maintains the temperature of the *emission spot*, so long as a current of a few amperes continues.

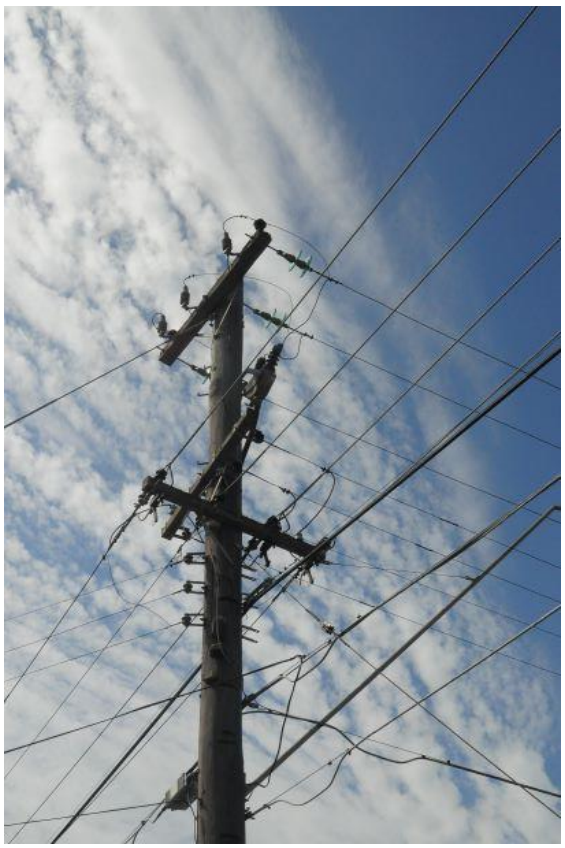
While the current is carried by electrons, the positive ions returning to the cathode allow the conduction path to be largely unaffected by the space charge effects which limit the performance of vacuum tubes. Consequently, the valve can carry high currents at low *arc voltages* (typically 20-30 V) and so is an efficient rectifier. Hot-cathode, gas discharge tubes such as the thyratron may also achieve similar levels of efficiency but heated cathode filaments are delicate and have a short operating life when used at high current.

The temperature of the envelope must be carefully controlled, since the behaviour of the arc is determined largely by the vapour pressure of the mercury, which in turn is set by the coolest spot on the enclosure wall. A typical design maintains temperature at 40 °C (104 °F) and a mercury vapour pressure of 7 millipascals.

The mercury ions emit light at characteristic wavelengths, the relative intensities of which are determined by the pressure of the vapour. At the low pressure within a rectifier, the light appears pale blue-violet and contains much ultraviolet light.

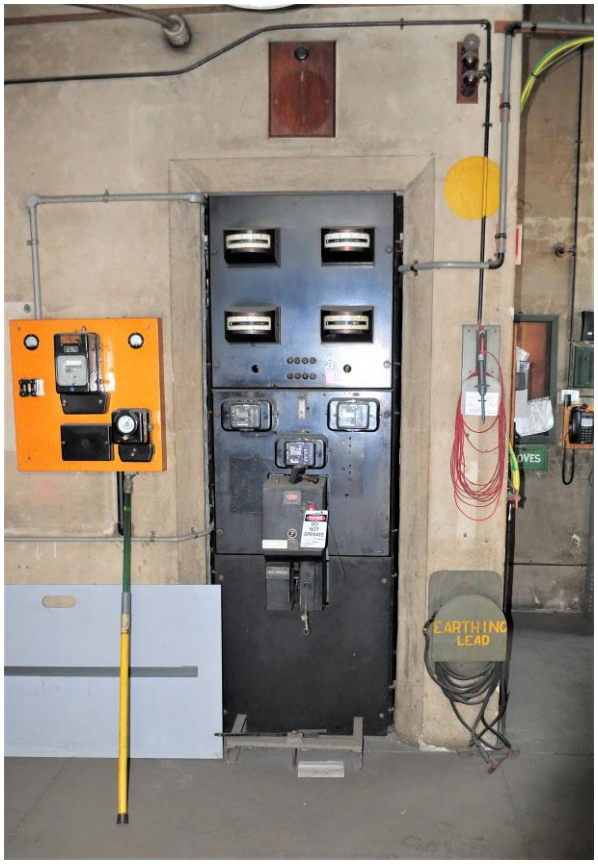
[13] Wikipedia, Mercury-arc Valve. https://en.wikipedia.org/wiki/Mercury-arc_valve

Appendix 3: Photographs and Captions

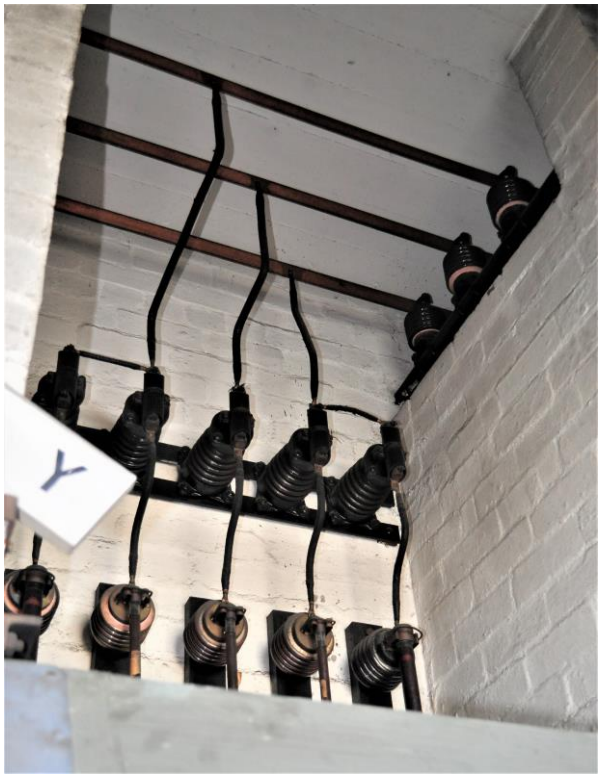


6.6 kV supply feeder at the corner of Dawson and Moule Streets about 100 metres from the substation. The pothead for the 6.6 kV cable which feeds the substation can be seen to the right of the pole just below the upper (6.6 kV) circuit. The lower part of the pole carries a low voltage (415/240 Volt) three phase distribution circuit, service cables to surrounding houses and various telecommunications circuits.
Image: Owen Peake

5 kVA Auxiliary Transformer in centre bay of 6.6 kV switchgear.
Image: Owen Peake



6.6 kV Oil Circuit Breaker front panel for rectifier supply.
Image: Owen Peake.



6.6 kV busbar (above) and connection to auxiliary Transformer.
Image: Owen Peake.

6.6 kV Oil Circuit Breaker rear panel for rectifier supply.
Image: Owen Peake.

Transformer nameplate. Image: Owen Peake.

Knife switch acts as an isolator for the negative circuit breaker. The current in this switch could be up to 1000 Amps. Image: Owen Peake.

Very neat wiring on the back of the 600 Volt DC Switchboard.
Image: Owen Peake.

Architectural detail in the front wall of the substation clearly dates the building to circa 1930. Image: Owen Peake.

References:

Miles Pierce. Brunswick West Tramway Substation “W”. Report on visit by Miles Pierce. Engineering Heritage Victoria. 16 July 2014.

Geoff Brown. The tram through the park: the origins of the West Coburg tramway. Melbourne Tram Museum paper. 2016.

http://www.hawthorntramdepot.org.au/papers/westcoburg.htm

CHANGE CONTROL

VERSION 1	**6 JANUARY 2019**	**2331 WORDS**	
VERSION 2	**7 JANUARY 2019**	**3256 WORDS**	
VERSION 3	**1 FEB 2019 (MCP review)**	**3244 WORDS**	
VERSION 4	**11 MARCH 2019**	**3604 WORDS**	**PRIOR TO ADDING MORE IMAGES**
VERSION 5	**11 MARCH 2019**	**3604 WORDS**	**10 IMAGES ADDED**
VERSION 6	**28 MARCH 2019**		**TRACK CHANGES FROM MP**
VERSION 7	**28 MARCH 2019**	**3789 WORDS**	**MP CHANGES ACCEPTED**
VERSION 8	**15 APRIL 2019**	**3808 WORDS**	**DLL CHANGES ACCEPTED**
VERSION 9	**27 APRIL 2019**	**3816 WORDS**	**CORRECTED P10 PARA 2: “A SINGLE” TO “A PAIR OF”**
VERSION 10	**2 AUGUST 2019**	**3890 WORDS**	**ADDED LOCATION AND FLOOR PLAN AT 5.1, P9 AND ONE SPELLING CORRECTION ON P13 – ‘THYRISTOR’**
VERSION 11	**3 NOV 2019**	**3873 EORDS**	**CLARIFIED OPERATIONAL DATES AT PAGE 7 BY ADDING NOTE.**